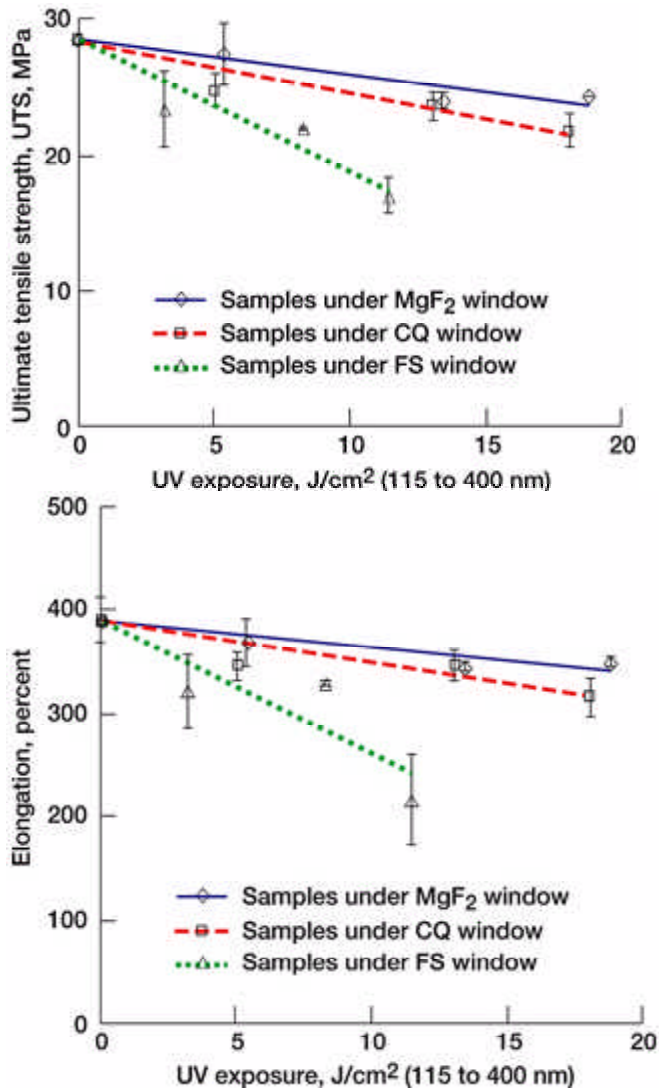


Effects of Various Wavelength Ranges of Vacuum Ultraviolet Radiation on Teflon FEP Film Investigated

Teflon FEP films (DuPont) have been widely used for spacecraft thermal control and have been observed to become embrittled and cracked upon exposure to the space environment (refs. 1 and 2). This degradation has been attributed to a synergistic combination of radiation and thermal effects (refs. 1 and 3). A research study was undertaken at the NASA Glenn Research Center to examine the effects of different wavelength ranges of vacuum ultraviolet (VUV) radiation on the degradation of the mechanical properties of FEP. This will contribute to an overall understanding of space radiation effects on Teflon FEP, and will provide information necessary to determine appropriate techniques for using laboratory tests to estimate space VUV degradation. Research was conducted using in-house facilities at Glenn and was carried out, in part, through a grant with the Cleveland State University.

Samples of Teflon FEP film of 50.8- μ m thickness were exposed to radiation from a VUV lamp from beneath different cover windows to provide different exposure wavelength ranges: MgF₂ (115 to 400 nm), crystalline quartz (140 to 400 nm), and fused silica (FS, 155 to 400 nm). Following exposure, FEP film specimens were tensile tested to determine the ultimate tensile strength and elongation at failure as a function of the exposure duration for each wavelength range. The graphs show the effect of ultraviolet exposure on the mechanical properties of the FEP samples.

In order to interpret the effects of exposure to the various wavelength ranges, it is important to understand the nature of the interaction of ultraviolet radiation with Teflon FEP. Teflon PTFE, which is chemically similar to FEP, has been found to have an absorption peak at approximately 160 nm (ref. 4). VUV radiation of wavelengths in this absorption peak are absorbed significantly within a very thin slice of the Teflon thickness, resulting in a concentration of photoreactions near the surface. One consequence of surface-concentrated photoreactions is erosion. Surface erosion was observed upon exposure of FEP to both broad spectrum VUV (115 to 400 nm) and monochromatic VUV (147 nm) (ref. 5). In comparison, mechanical properties degradation of FEP was caused by 115- to 400-nm VUV, but not by 147-nm VUV (ref. 5). This implies that wavelengths that cause erosion cannot penetrate into the polymer deeply enough to embrittle the bulk material. Typical laboratory VUV sources have a peak output at approximately 160 nm, which matches the absorption peak of Teflon but which is not representative of a peak in the solar spectrum. Therefore, it is likely that laboratory VUV exposure with these sources would cause greater surface erosion than would occur in space (ref. 6), and may lead to inaccuracies in interpreting the results of ground laboratory tests of Teflon materials in terms of expected degradation in the space environment.



Effects of ultraviolet radiation on 50.8- μ m FEP, where UV was provided by broad spectrum VUV lamps transmitted through cover-windows of MgF₂ (115 to 400 nm), CQ (140 to 400 nm), and FS (155 to 400 nm). Left: Effects of ultraviolet radiation on ultimate tensile strength. Right: Effects of ultraviolet radiation on elongation to failure. The x-axis is VUV fluence in units of joules/square centimeter. Results show a significantly more rapid rate of degradation for samples exposed from beneath FS than from beneath MgF₂ and CQ.

Examining the data in the graphs, we see that the fastest rate of mechanical properties degradation is for FEP exposed to 155- to 400-nm wavelengths (from beneath fused silica). Whereas the cut-on wavelength for fused silica is 155 nm, transmittance through fused silica does not approach a maximum until approximately 180 nm, so the vast majority of the VUV lamp's output peak centered at 160 nm is not transmitted through fused silica to the sample. Both the crystalline quartz (CQ) and magnesium fluoride (MgF₂) windows allow the 160-nm output peak to be transmitted with minimal attenuation, and therefore, provide a significant fluence of surface-eroding wavelengths of

VUV in addition to wavelengths that can cause degradation deeper in the material. The apparent slower rate of mechanical properties degradation for samples exposed from beneath the CQ and MgF₂ windows is due to the fact that the total VUV fluence for these cases includes fluence that only thins the material and does not lead to embrittlement, and, in fact, may remove an embrittled layer. When the eroding wavelengths are excluded from the VUV exposure test, laboratory testing results are expected to produce a more conservative estimate of in-space degradation and may be appropriate for determining worst-case effects. The results of this research study are presented in reference 6.

References

1. Townsend, J.A., et al.: Ground-Based Testing of Replacement Thermal Control Materials for the Hubble Space Telescope. High Per. Polym., vol. 11, no. 1, 1999, pp. 63-79.
2. Dever, J.A., et al.: Mechanical Properties of Teflon® FEP Retrieved From the Hubble Space Telescope. High Per. Polym., vol. 13, no. 3, 2001, pp. S373-S390.
3. de Groh, K.K., et al.: Thermal Contributions to the Degradation of Teflon® FEP on the Hubble Space Telescope. High Per. Polym., vol. 13, no. 3, 2001, pp. S401-S420.
4. Seki, K., et al.: Electronic-Structure of Poly(Tetrafluoroethylene) Studied by UPS, VUV Absorption, and Band Calculations. Phys. Scr., vol. 41, no. 1, 1990, pp. 167-171.
5. Skurat, V.E., et al.: The Separate and Combined Effects of VUV Radiation and Fast Atomic Oxygen on Teflon® FEP and Silicon Carbide. ESA SP 399, 1997, pp. 267-279.
6. Dever, Joyce A.; and McCracken, Cara A.: Effects of Various Wavelength Ranges of Vacuum Ultraviolet Radiation on Teflon® FEP Film. ESA SP 540, 2003, pp. 367-373.

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